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(71) Applicant:
MITSUBISHI DENKI KABUSHIKI KAISHA
Tokyo 100-8310 (JP)

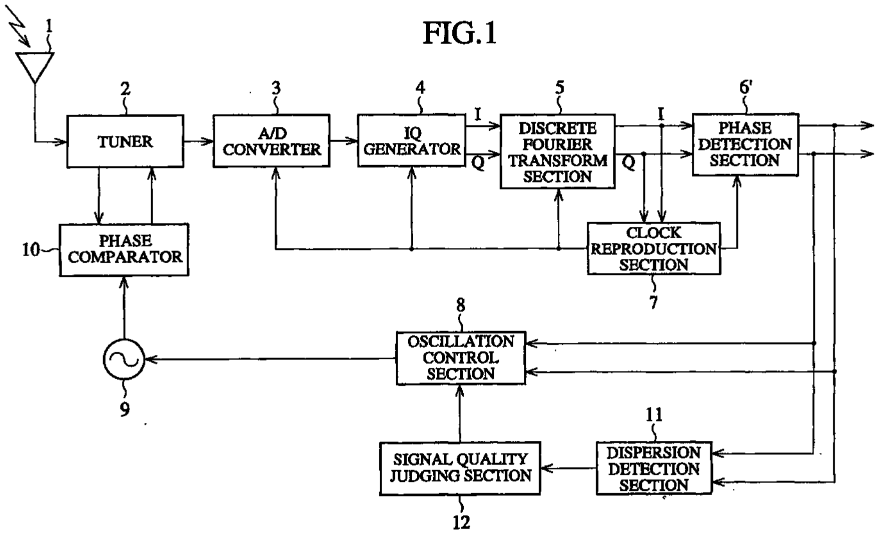
(72) Inventors:
- **TAKEUCHI, Mitsuru**
  Mitsubishi Denki K.K.
  Tokyo 100-8310 (JP)
- **SAKAGUCHI, Tadashi,**
  Mitsubishi Denki Engin. K.K.
  Tokyo 100-0004 (JP)
- **MORITA, Masakazu**
  Mitsubishi Denki Kabushiki Kaisha
  Tokyo 100-8310 (JP)

(74) Representative:
Pfenning, Meinig & Partner
Mozartstrasse 17
80336 München (DE)

(54) **SIGNAL MODULATOR AND RECEIVING CONTROL METHOD FOR THE SIGNAL MODULATOR**

(57) When the control of synchronization performed in the radio wave receiver is started, the phase detection section 6' calculates the phases by use of the detected phase data input from the discrete Fourier transform section 5, the dispersion detection section 11 converts the phase from the phase detection section 6' into phase errors, and the signal quality judging section 12 judges the dispersed state of the phase errors. Thereafter, when the quality judging section 12 checks whether there is a dispersion, and judges that it is positive, then it instructs a certain correction control amount (for example $\pi/2$) to the oscillator control section 8, whereas when it judges that there is no dispersion, then it instructs no correction control (step ST16). Finally, the oscillator control section 8 terminates the control of the synchronization depending on whether there is an instruction of correction control from the dispersion detection section 11.

FIG.1



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Description

BACKGROUND OF THE INVENTION

Technical Field

[0001] The present invention relates to a signal decoding device which is capable of correctly receiving carrier waves necessary for modulated signals such as OFDM (Orthogonal Frequency Division Multiplex) signals configured by a plurality of sub-carriers in a good state, yet without getting into a false locked phenomenon, and also relates to a method of controlling the reception of modulated signals by use of the signal decoding device.

Background Art

[0002] Fig. 14 is a schematic diagram showing a conventional signal decoding device, which is used for correctly and excellently receiving carrier waves (or may be referred to just as "carriers" hereinafter) necessary for decoding modulated signals configured by a plurality of sub - carriers; specifically for receiving DAB (Digital Audio Broadcasting) signals modulated by the OFDM modulation method. In the figure, reference numeral 2 denotes a tuner that converts a radio wave received through a receiving antenna 1 into a signal of the medium frequency band, numeral 4 denotes an IQ generator section that divides a digital data, which is generated in and fed from an A/D converter 3, into an I signal component (real-number unit) and a Q signal component (imaginary-number unit), and numeral 5 denotes a discrete Fourier transform section that carries out Fourier transformation to these I and Q signal components so as to modulate a time-mode signal to a frequency-mode signal.

[0003] Further, reference numeral 6 denotes a differential coding section that calculates the difference between the phase of a carrier configuring the OFDM signal and the phase of the carrier which is one OFDM symbol before that phase from the modulated I signal component data and the Q signal component data as to all the carriers, numeral 7 denotes a clock reproduction section that detects and corrects a timing discrepancy of the synchronization between the transmission side and the reception side, so as to reproduce clock signals without any discrepancy in the synchronization, and controls the A/D converter 3, the IQ generator section 4, the discrete Fourier transform section 5 and the differential coding section 6. Reference numeral 8 denotes an oscillator control section that controls a local oscillator 9 to vary the oscillation frequency in accordance with the phase difference of the carrier, numeral 10 denotes a phase comparator for controlling the tuner 2 so as to equalize the oscillation frequency of the local oscillator 9 and that of a local oscillator contained in the tuner 2.

[0004] Fig. 15 is an illustration that represents 4 values transmitted in the QPSK (Quadrature Phase Shift Keying) modulation mode, and Fig. 16 is an illustration indicating the state that a carrier has been advanced for $\pi/2$ in the QPSK modulation mode. The modulating method of carriers employed in the DAB is of the DQPSK (Differential Quadrature Phase Shift Keying) modulation, whereby the carriers can be represented in digital values; namely I signal component and Q signal component by carrying out the Fourier transformation, and if, as shown in Fig. 15, the axis of abscissa indicates the I signal component, and that of ordinates indicates the Q component, the 4 values (I,Q) can be represented as (0,0), (0,1), (1,0) and (1,1), respectively. That is, the phase error becomes zero at these 4 points.

[0005] At this tine, if for example, as shown in Fig. 16, the data that has to take the value (I,Q) = (0,0) is shifted for $\pi/2$ phase, it coincides with the value (I,Q) = (0,1), and on this occasion the differential coding section 6 judges that there is no discrepancy in phase, in spite of the fact that the data has been shifted for $\pi/2$ phase.

[0006] The operation of the conventional signal decoding device is as follows.

[0007] Fig. 17 is a flow chart showing an exemplary case of the control operation for receiving the DAB signals in the conventional signal decoding device.

[0008] When the control of synchronization performed in the radio wave signal receiver is started, the differential coding section 6 judges the phase difference by use of the detected phase data input from the discrete Fourier transform section 5 (step ST1), and when it judges that the phase error is $\pi/8$ (step ST2), then it outputs a data corresponding to the correction of $\pi/8$ to the oscillator control section 8. Thereafter, the oscillator control section 8 controls the local oscillator 9 to carry out synchronization on the basis of the data corresponding to the correction of $\pi/8$ (step ST3), and then terminates the control operation. By carrying out these steps at predetermined periods, the signal reception in good condition can be obtained.

[0009] However, if the phase error judged in step ST2 by use of the detected phase data is $\pi/2$, the detected phase data coincides with the next value of the 4 values {(I,Q) = (0,0), (0,1), (1,0), (1,1)}, and thus it is erroneously judged that it is in the synchronized state, so that the differential coding section 6 does not instruct any correction control. For this reason, the oscillator control section 8 does not perform any correction control of the local oscillator 9, and thus terminates the control operation erroneously. The erroneous judgment is referred to as a "false lock" hereinafter.

[0010] Consequently, when there is a phase discrepancy of a carrier for + $\pi/2$ for some reason or other during the control operation of the carrier synchronization, the conventional DAB signal receiver 2 would judge that there has been no phase discrepancy.

[0011] Since the conventional signal decoding device and a method of controlling the signal reception implemented therein are constructed as such, when a signal including a phase error that could cause the false lock is received, there has been caused such a problem that the signal decoding device could not properly receive the modulated signal without error.

[0012] The present invention has been proposed to solve the problems aforementioned, and it is an object of the present invention to provide a signal decoding device which is capable of correctly receiving carriers necessary for PFDM modulated signals in a good state, yet without getting into the false locked state, and also a method of controlling the signal reception implemented therein.

DISCLOSURE OF THE INVENTION

[0013] In order to achieve the above object, the signal decoding device according to the present invention is constructed in such a manner as to calculate phase errors from detected phases, detect the dispersed state of the thus calculated phase errors, judge whether or not the decoded signal is of good quality from the detected dispersed state of the phase errors, and output the result of judgment to the oscillator control section.

[0014] Due to this, by referring the dispersed state output from the dispersion detection section to the relation between the phase errors and the dispersion thereof in the signal quality judging section so as to judge the signal quality, such an effect can be efficiently obtained that carrier waves required for phase-modulated broadcast signals such as OFDM signals configured by a plurality of sub-carriers can be correctly received in a good state, yet without getting into a false locked phenomenon.

[0015] The signal decoding device according to the present invention is constructed in such a manner as to calculate phase errors from the calculated phase differences, detect the dispersed state of the thus calculated phase errors, judge whether or not the decoded signal is of good quality from the detected dispersed state of the phase errors, and output the result of judgment to the oscillator control section.

[0016] Due to this, by referring the dispersed state output from the dispersion detection section to the relation between the phase errors and the dispersion thereof in the signal quality judging section so as to judge the signal quality, such an effect can be efficiently obtained that carrier waves required for differential phase-modulated broadcast signals such as OFDM signals configured by a plurality of sub-carriers can be correctly received in a good state, yet without getting into a false locked phenomenon.

[0017] The signal decoding device according to the present invention is constructed in such a manner as to calculate phase errors from the calculated phase differences, detect the dispersed state of the thus calculated phase errors in a stepwise manner, judge in a stepwise manner whether or not the decoded signal is of good quality from the detected stepwise dispersed state of the phase errors, output the judgment result, vary the control amount in a stepwise manner in accordance with the judged stepwise qualities when calculating the control amount from the mean value of the phase errors, and vary the oscillation frequency of a local oscillator on the basis of this control amount

[0018] Due to this, the signal receiving device can be efficiently controlled by judging the signal quality in a stepwise manner in accordance with the dispersed state of the detected phase errors, and by controlling in a stepwise manner the frequency and the phase of a local oscillation signal used for decoding operation.

[0019] The signal decoding device according to the present invention is constructed in such a manner as to feed, for carrying out an audio control, the judgment result of the dispersed state detected in a stepwise manner to an audio control section, which in turn determines a muting amount in accordance with the detection result of the stepwise dispersed state.

[0020] Due to this, the signal quality is judged in a stepwise manner in accordance with the dispersed state of the detected phase errors, and the muting amount is controlled on the basis of the result of the judgment, so that such an effect can be obtained that a queer sound generated in accordance with the deterioration of the decoded signal is suppressed.

[0021] The signal decoding device according to the present invention is constructed in such a manner that the audio control section determines the control amount of high-pitch tone from the stepwise detection result of the dispersed state,

[0022] Due to this, such an effect can be obtained that a queer sound generated in accordance with the deterioration of the decoded signal is suppressed.

[0023] The method of controlling the signal reception in the signal decoding device according to the present invention is arranged in such a manner as to calculate phase errors from the calculated phase differences, detect the dispersed state of the thus calculated phase errors, judge whether or not the decoded signal is of good quality from the detected dispersed state of the phase errors, and output the result of judgment to the oscillator control section.

[0024] Due to this, by referring the dispersed state output from the dispersion detection section to the relation between the phase errors and the dispersion thereof so as to judge the signal quality, such an effect can be efficiently obtained that carrier waves required for the OFDM signals configured by a plurality of sub-carriers can be correctly received in a good state, yet without getting into a false locked phenomenon.

[0025] The method of controlling the signal reception in the decoding device according to the present invention is arranged in such a manner as to calculate phase errors from the calculated phase differences, detect the dispersed state of the thus calculated phase errors in a stepwise manner, judge in a stepwise manner whether or not the decoded signal is of good quality from the detected dispersed state of the phase errors, output the judgment result, vary the control amount in a stepwise manner in accordance with the judged stepwise qualities when calculating the control amount from the mean value of the phase errors, and vary the oscillation frequency of a local oscillator on the basis of the control amount.

[0026] Due to this, the signal receiving device can be controlled more efficiently by judging the signal quality in a stepwise manner in accordance with the dispersed state of the detected phase errors, and by controlling in a stepwise manner the frequency and the phase of a local oscillation signal used for decoding operation.

[0027] The method of controlling the signal reception in the signal decoding device according to the present invention is arranged in such a manner as to feed, for carrying put an audio control, the judgment result of the dispersed state detected in a stepwise manner to an audio control section; which in turn determines a muting amount in accordance with the detection result of the stepwise dispersed state.

[0028] Due to this, the signal quality is judged in a stepwise manner in accordance with the dispersed state of the detected phase errors, and the muting amount is controlled on the basis of the result of the judgment, so that such an effect can be acquired that a queer sound generated in accordance with the deterioration of the decoded signal is suppressed.

[0029] The control method of signal reception in the signal decoding device according to the present invention is arranged in such a manner that the audio control section determines the control amount of high-pitch tone from the stepwise detection result of the dispersed state,

[0030] Due to this, such an effect can be acquired that a queer sound generated in accordance with the deterioration of the decoded signal is suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031]

Fig. 1 is a schematic diagram showing a signal decoding device according to a first embodiment of the present invention.

Fig. 2 is a flow chart showing an exemplary case of the control operation for receiving the DAB signals carried out in the signal decoding device according to the first embodiment of the present invention.

Fig. 3 is an illustration showing the dispersion of detected phase errors in the case where the level of discrepancy is small in the signal decoding device according to the first embodiment of the present invention.

Fig. 4 is an illustration showing the dispersion of detected phase errors in the case where the level of discrepancy is greater than the case of Fig. 3 in the signal decoding device according to the first embodiment of the present invention.

Fig. 5 is an illustration showing the dispersion of detected phase errors in the case where the level of discrepancy is further greater than the case of Fig. 4 in the signal decoding device according to the first embodiment of the present invention.

Fig. 6 is an illustration showing the relation between the level of discrepancy end detected phase errors in the signal decoding device according to the present invention.

Fig. 7 is a schematic diagram showing a signal decoding device according to a second embodiment of the present invention

Fig. 8 is a flow chart showing an exemplary case of the control operation for receiving the DAB signals in the signal decoding device according to the second embodiment of the present invention.

Fig. 9 is a schematic diagram showing a signal decoding device according to a third embodiment of the present invention

Fig. 10 is a flow chart showing an exemplary case of the control operation for receiving the DAB signals in the signal decoding device according to the third embodiment of the present invention.

Fig. 11 is a schematic diagram showing a signal decoding device according to a fourth embodiment of the present invention

Fig. 12 is a flow chart showing an exemplary case of the control operation for receiving the DAB signals in the signal decoding device according to the fourth embodiment of the present invention.

Fig. 13 is a flow chart showing an exemplary case of the control operation for receiving the DAB signals in the signal decoding device according to the fifth embodiment of the present invention.

Fig. 14 is a schematic diagram showing a conventional signal decoding device.

Fig. 15 is an illustration representing 4 values transmitted in the QPSK modulation mode.

Fig. 16 is an illustration showing the state in which a carrier has been advanced for $\pi/2$ in the QPSK modulation mode.

Fig. 17 is a flow chart showing an exemplary case of the control operation for receiving the DAB signals in the conventional signal decoding device.

BEST MODE FOR CARRYING OUT THE INVENTION

[0032] Several embodiments for carrying out best the present invention are now explained with reference to attached drawings, in order to explain the present invention to details.

[First Embodiment]

[0033] Fig. 1 is a schematic diagram showing a signal decoding device according to a first embodiment of the present invention. In the figure, reference numeral 2 denotes a tuner that converts a radio wave received through a receiving antenna 1 into a signal of the medium frequency band, numeral 4 denotes an IQ generator section that divides a digital data, which is generated in and fed from an A/D converter 3, into an I signal component (real-number unit) and a Q signal component (imaginary-number unit), and numeral 5 denotes a discrete Fourier transform section that carries out Fourier transformation to these I and Q signal components so as to modulate a time-mode signal to a frequency-mode signal. Reference numeral 6' denotes a phase detection section that detects the phase of all the carriers configuring OFDM signals from the frequency-modulated I component data and Q component data, numeral 7 denotes a clock reproduction section that detects and corrects a timing discrepancy of the synchronization between the transmission side and the reception side, so as to reproduce clock signals without any discrepancy in the synchronization, and controls the A/D converter 3, the IQ generator section 4, the discrete Fourier transform section 5 and the phase detection section 6'.

[0034] Further, reference numeral 8 denotes an oscillator control section that controls a local oscillator 9 to vary the oscillation frequency in accordance with the phase of the carrier output from the phase detection section 6'. When the oscillator control section 8 calculates a control amount from the mean value of phase errors, it varies the control amount in accordance with the signal quality judged in the signal quality judging section 12. For example, when it is judged in the signal quality judging section 12 that the signal is of good quality, the oscillator control section 8 applies a control amount calculated from the mean value of the phase errors, or otherwise it applies a predetermined control amount (for example an mount corresponding to $\pi/2$) irrespective of the control amount calculated from the mean value of the phase errors. Thereafter, the oscillation frequency of the local oscillator 9 is varied in accordance with the control amount fed from the oscillator control section 8.

[0035] Reference numeral 10 denotes a phase comparator for controlling the tuner 2 to equalize the oscillation frequency of the local oscillator 9 and that of a local oscillator contained in the tuner 2, numeral 11 denotes a dispersion detection section that detects the dispersed state of the phase errors, which are obtained from the phases calculated beforehand, and numeral 12 denotes a signal quality judging section 12 that judges the quality of the decoded signal on the basis of the dispersed state detected in the dispersion detection section 11, and outputs the result of the judgment to the oscillator control section 8.

[0036] The operation of the signal decoding device according to the first embodiment of the present invention is as follows.

[0037] Fig. 2 is a flow chart showing an exemplary case of the control operation for receiving the DAB signals in the signal decoding device according to this embodiment.

[0038] When the control of synchronization performed in the radio wave receiver is started, the phase detection section 6' calculates the phase by use of the detected phase data input from the discrete Fourier transform section 5 (step ST11), the dispersion detection section 11 converts the phase fed from the phase detection section 6' into phase errors (step ST12), and the signal quality judging section 12 judges the dispersed state of the phase errors (step ST13).

[0039] Thereafter, when the quality judging section 12 checks whether there is a dispersion (step ST14), and judges that it is positive, then it instructs a certain correction control amount (for example $\pi/2$) to the oscillator control section 8 (step ST15), whereas when it judges that there is no dispersion, then it instructs no correction control (step ST16). Finally, the oscillator control section 8 terminates the control of the synchronization depending on whether there is an instruction of correction control from the dispersion detection section 11 (step ST17). By carrying out these steps at predetermined periods, the signal reception in good condition can be obtained.

[0040] Fig. 3 is an illustration showing the dispersion of detected errors in the case where the level of discrepancy is small in the signal decoding device according to the first embodiment of the present invention, Fig. 4 is an illustration showing the dispersion of detected phase errors in the case where the level of discrepancy is greater than the case of Fig. 3 in the signal decoding device according to the first embodiment of the present invention, Fig. 5 is an illustration showing the dispersion of detected phase errors in the case where the level of discrepancy is further greater than the case of Fig. 4 in the signal decoding device according to the first embodiment of the present invention, and Fig. 6 is an illustration showing the relation between the level of discrepancy and the detected phase errors in the signal decoding device according to the first embodiment of the present invention.

[0041] When the discrepancy level of the frequency of the transmission side and that of the reception side is small in the case that OFDM modulation signal is transmitted in compliance with the DAB standard, the detected phase errors depicted per each sampling will be as shown in Fig. 3. Similarly, the case in which the level of discrepancy is greater, and the case in which the level of discrepancy is smaller are as shown in Figs. 4 and 5, respectively, so that the relation between the detected phase errors and the dispersion thereof in the signal decoding device according to the present invention will be as shown in Fig. 6. By use of this relationship, the signal quality can be judged from the dispersed state of the phase errors. For example, when the dispersion is greater than the point b in Fig. 6, it can be judged that the absolute value of the discrepancy is large, so that it can be judged that the signal quality is not good, whereas in the case of the range between a and b, it can be judged that the signal is of good quality.

[0042] As explained above, according to the first embodiment, when the signal quality judging section 12 compares the dispersed state input from The dispersion detection section 11 to the relation between the phase errors and the dispersion thereof, it can judge the signal quality, so that in the case where phase-modulated signals such as OFDM signals configured by a plurality of carriers are to be received, carriers necessary for those signals can be correctly received in a good state, yet without getting into a false locked state.

[Second Embodiment]

[0043] Fig. 7 is a schematic diagram showing a signal decoding device according to a second embodiment of the present invention.

[0044] For example, it shows a configuration example of a receiving device for receiving OFDM modulation signals transmitted in compliance with the DAB standard. In the figure, as the same reference numerals as those in the first embodiment indicate the same or similar portions, the explanation thereabout is omitted. Reference numeral 13 denotes a differential coding section that calculates the difference between the phase of a carrier configuring the OFDM signal and the phase of the carrier which is one OFDM-symbol before that phase from the I component data and Q component data which are frequency modulated in the discrete Fourier transform section 5 as to all the carriers, reference numeral 8 denotes an oscillator control section that controls a local oscillator 9 to vary the oscillation frequency in accordance with the phase difference of the carrier, and calculates a control amount from the mean value of the phase errors. Further, reference numeral 11 denotes a dispersion detection section that detects the dispersed state of the phase errors, which are obtained from the phases calculated beforehand, and all other portions operate just as those in the first embodiment.

[0045] The operation of the signal decoding device according to the second embodiment of the present invention is as follows.

[0046] Fig. 8 is a flow chart showing an exemplary case of the control operation for receiving the DAB signals in the signal decoding device according to this embodiment.

[0047] When the control of synchronization performed in the signal receiver is started, the differential coding section 13 calculates the phase difference by use of the detected phase data input from the discrete Fourier transform section 5 (step ST21), the dispersion detection section 11 converts the phase difference from the differential coding section 13 into phase errors (step ST22), and the signal quality judging section 12 judges the dispersed state of the phase errors (step ST23).

[0048] Thereafter, when the signal quality judging section 12 checks whether there is a dispersion (step ST24), and judges that it is positive, then it instructs a certain correction control amount (for example $\pi/2$) to the oscillator control section 8 (step ST25), whereas when it judges that there is no dispersion, then it instructs no correction control (step ST26). Finally, the oscillator control section 8 terminates the control of the synchronization depending on whether there is an instruction of correction control from the dispersion detection section 11 (step ST27). By carrying out these steps at predetermined periods, the signal reception in good condition can be obtained.

[0049] As explained above, according to the second embodiment, when the signal quality judging section 12 compares the dispersed state input from the dispersion detection section 11 to the relation between the phase errors and the aspersion thereof, it can judge the signal quality, so that in the case where differential phase-modulated broadcast signals such as OFDM signals configured by a plurality of carriers are to be received, carriers necessary for those signals can be correctly received in a good state without getting into a false locked state.

[Third Embodiment]

[0050] Fig. 9 is a schematic diagram showing a signal decoding device according to a third embodiment of the present invention.

[0051] For example, it shows a configuration example of a receiving device for receiving OFDM modulation signals transmitted in compliance with the DAB standard. In the figure, as the same reference numerals as those in the first and second embodiments indicate the same or similar portions, the explanation thereabout is omitted. Reference numeral 14 denotes a stepwise dispersion detection section that detects in a stepwise manner the dispersed state of the phase errors, which are calculated from the phase difference obtained in the differential coding section 13, and numeral 18 denotes a stepwise signal quality judging section that judges the quality of the decoded signal on the basis of the dispersed state detected in the dispersion detection section 14 in a stepwise manner, and outputs the result of the judgment to the stepwise oscillator control section 19.

[0052] Although the stepwise oscillator control section 19 calculates a control amount from the mean value of the phase errors, in this case, it is a stepwise oscillator control section that varies the control amount in a stepwise manner in accordance with the signal quality of the signal judged in the stepwise signal quality judging section 18, and it varies the oscillation frequency of the local oscillator 9 in accordance with the control amount fed from the stepwise oscillator control section 19.

[0053] The phase comparator 10 controls the tuner 2 so as to equalize the oscillation frequency of the local oscillator 9 and that of a local oscillator contained in the tuner 2.

[0054] The operation of the signal decoding device according to the third embodiment of the present invention is as follows.

[0055] Fig. 10 is a flow chart showing an exemplary case of the control operation for receiving the DAB signals in the signal decoding device according to this embodiment.

[0056] When the control of synchronization performed in the signal receiver is started, the differential coding section 13 calculates the phase difference by use of the detected phase data input from the discrete Fourier transform section 5 (step ST31), the stepwise dispersion detection section 14 converts the phase difference from the differential coding section 13 (step ST32) into phase errors, and the stepwise signal quality judging section 18 judges the dispersed state of the phase errors (step ST33) in a stepwise manner. Thereafter, when the stepwise signal quality judging section 18 checks whether there is a large dispersion (step ST34), and judges that it is positive, then it instructs a certain correction control amount (for example $\pi/2$) to the stepwise oscillator control section 19 (step ST35).

[0057] On the other hand, when it judges that the dispersion therein is not large, but of the intermediate level, then it instructs a certain correction control amount which is different from the that of the case of a large dispersion, for example an amount that corresponds to $\pi/4$, to the stepwise oscillator control section 19 (step ST37), and further, when it judges that the dispersion therein is small in step ST36, then it instructs no correction control to the stepwise oscillator control section 19 (step ST38). Finally, the stepwise oscillator control section 19 terminates the control of the synchronization depending on whether there is an instruction of correction control from the stepwise dispersion detection section 14 (step ST39). By carrying out these steps at predetermined periods, the signal reception in good condition can be obtained.

[0058] The relation between the detected phase errors and the dispersion thereof will be as shown in Fig. 6 as indicated by the first embodiment, wherein the stepwise dispersion detection section 14 detects whether the dispersion is in such a sate, as shown in Fig. 4, that the detected phase errors largely disperse equally to the positive and negative sides from the respective broken lines, or whether in such a state as shown in Fig. 5 that some of those are smaller than the broken lines equally to the both positive and negative sides, or tether in such a state as shown in Fig. 3 that there is no dispersion thereof. In other words, the stepwise dispersion detection section 14 determines in a stepwise manner by judging in which one of the points a to c of Fig. 6 the dispserion resides.

[0059] The stepwise signal quality judging section 18 judges the signal quality in a stepwise manner in accordance with the result of the stepwise detection of the dispersed state. For example, in Fig. 6, the dispersed state at the point a indicates that the signal quality is good, at c indicates that the phase error is quite large and thus the signal quality is bad, and at b indicates that the signal quality is in the intermediate level.

[0060] The stepwise oscillator control section 19 varies the control amount in a stepwise manner on the basis of the signal quality judged in a stepwise manner. For example, it varies the control amount either to a control amount calculated based on the mean value of the phase errors, to a certain control amount (corresponding to $\pi/2$ for example), or to a half that amount (corresponding to $\pi/4$ for example).

[0061] As explained above, the signal quality is judged in a stepwise manner on the basis of the dispersed state of the detected phase errors according to the third embodiment, and the frequency and phase of the local oscillation signal used for signal decoding operation are controlled in different stages, so that the control of the receiving device can be more efficiently carried out than the second embodiment.

[Fourth Embodiment]

[0062] Fig. 11 is a schematic diagram showing a signal decoding device according to a fourth embodiment of the present invention, and for example, it shows a configuration example of a receiving device for receiving OFDM modulation signals transmitted in compliance with the DAB standard. In the figure, as the same reference numerals as those in the first, second and third embodiments indicate the same or similar portions; the explanation thereabout is omitted. The result of detection of the dispersed state detected in the stepwise dispersion detection section 17 in a stepwise manner is input to an audio control section 15, and the muting amount can be determined in the audio control section 15 in accordance with the detection result of the dispersed state. For example, the audio control can be performed in such a manner as to carry out sating operation only when there is dispersion as shown in Fig. 5.

[0063] The operation of the signal decoding device according to the forth embodiment of the present invention is as follows.

[0064] Fig. 12 is a flow chart showing an exemplary case of the control operation for receiving the DAB signals in the signal decoding device according to this embodiment.

[0065] When the control of synchronization performed in the signal receiver is started, the differential coding section 13 calculates the phase difference by use of the detected phase data input from the discrete Fourier transform section 5 (step ST41), the stepwise dispersion detection section 17 converts the phase difference from the differential coding section 13 (step

ST42) into phase errors, and the stepwise signal quality judging section 18 judges the dispersed state of the phase errors (step ST43) in a stepwise manner. Thereafter, when the stepwise signal quality judging section 18 checks whether there is a large dispersion (step ST44), and judges that there is a large dispersion, then it controls the muting amount to fully reduce the acoustic volume with respect to the audio control section (step ST45).

[0066] On the other hand, when it is judged in step ST44 that the dispersion therein is not large, but of the intermediate level (step ST46), then the acoustic volume will not be fully reduced, but for a certain amount (step ST47), whereas when it is judged that there is no dispersion, then no muting control is performed (step ST48), and the volume control is terminated. By carrying out these steps at predetermined periods, a queer sound generated in accordance with the deterioration of the decoded signal can be sufficiently suppressed.

[0067] As explained above, according to the fourth embodiment, the signal quality is judged in a stepwise manner in accordance with the dispersed state of the detected phase errors, and the muting amount is controlled on the basis of the result of the judgment, so that such an effect can be obtained that a queer sound generated in accordance with the deterioration of the decoded signal is suppressed.

[Fifth Embodiment]

[0068] Since the construction of the fifth embodiment of the present invention is same as that of the fourth embodiment, explanation thereof is omitted here. Further, as the same reference numerals as those in the first to the fourth embodiments indicate the same or similar portions, the explanation thereabout is omitted. The result of the detection of the dispersed state detected in the stepwise dispersion detection section 17 in a stepwise manner is input to the audio control section 15, and the audio control section 15 determines a control amount of high-pitch tone (high-cut amount) in accordance with the detection result of the dispersed state in different stages, so as to perform an audio control.

[0069] The operation of the signal decoding device according to the fourth embodiment of the present invention is as follows.

[0070] Fig. 13 is a flow chart showing an exemplary case of the control operation for receiving the DAB signals in the signal decoding device according to this embodiment.

[0071] When the control of synchronization performed in the signal receiver is started, the differential coding section 13 calculates the phase difference by use of the detected phase data input from the discrete Fourier transform section 5 (step ST51), the stepwise dispersion detection section 17 converts the phase difference from the differential coding section 13 (step ST52) into phase errors, and the stepwise signal quality judging section 18 judges the dispersed state of the phase errors (step ST53) in a stepwise manner. Thereafter, when the stepwise signal quality judging section 18 checks tether there is a large dispersion (step ST54) and judges that there is a large dispersion, then it controls to fully reduce the high-pitch tone with respect to the audio control section (step ST55).

[0072] On the other hand, when it is judged in step ST54 that the dispersion therein is not large, but of the intermediate level (step ST56), then the high-pitch tone is reduced for a certain amount (step ST57), whereas when it is judged that there is no dispersion in step ST56, then no muting control is performed with respect to the audio control section 15 (step ST58), and the control of high-cut amount is terminated. By carrying out these steps at predetermined periods. a queer sound generated in accordance with the deterioration of the decoded signal can be suppressed without muting the sound.

[0073] As explained above, according to the fifth embodiment, the signal quality is judged in a stepwise manner in accordance with the dispersed state of the detected phase errors, and the muting of the high-pitch tone is controlled based on the result of the judgment, so that such an effect can be acquired that a queer sound generated in accordance with the deterioration of the decoded signal is suppressed without muting the sound.

Industrial Applicability

[0074] As explained heretofore, the signal decoding device and the method of controlling the signal reception by use of the signal decoding device according to the present invention are applicable to a signal decoding device and a method of controlling the signal reception therein, which requires ability to correctly receive carriers necessary for transmitting modulated signals such as OFDM signals configured by a plurality of subcarriers in a good state, yet without getting into a false locked state.

Claims

1. A signal decoding device comprising:

a tuner that converts a transmitted radio wave into a signal of predetermined medium frequency band,
an IQ generator section that converts the data converted by said tuner into a digital data, and divides said digital data into a real-number signal component and an imaginary-number signal component,
a discrete Fourier transform section that performs Fourier transformation to the real-number signal component and the imaginary-

number signal component generated in said IQ generator section so as to modulate a time-mode signal to a frequency-mode signal,

a phase detection section that detects and outputs the phases of a predetermined carrier, on the basis of the real-number signal component data and the imaginary-number signal component data transformed by said discrete Fourier transform section,

a dispersion detection section that calculates phase errors from the phases detected in said phase detection section, and detects the dispersed state of the phase errors, and

a signal quality judging section that judges the quality of the decoded signal on the basis of the dispersed state of the phase errors detected in said dispersion detection section.

2. A signal decoding device according to claim 1, wherein said phase detection section is enabled to adopt phase differences of all carriers configuring a broadcast signal, by substituting said phase detection section with a differential coding section that calculates and outputs the phase difference between the phase of a carrier and that of the carrier which is one symbol before that phase on the basis of the frequency-modulated real-number signal component data and imaginary-number signal component data.

3. A signal decoding device according to claim 1 further comprising:

an oscillator control section that controls a local oscillator in accordance with the phase difference of the carrier calculated by said differential coding section, and varies the oscillation frequency, and

a phase comparator that controls said tuner so as to equalize the oscillation frequency of said local oscillator controlled by said oscillator control section and that of a local oscillator contained in said tuner, wherein

said signal quality judging section outputs the resultant value of the judgment to said oscillator control section.

4. A signal decoding device according to claim 1, wherein said dispersion detection section detects in a stepwise manner the dispersed state of the phase errors, which are calculated from the phase difference calculated in said differential coding section, and

said signal quality judging section judges the quality of the decoded signal in a stepwise manner on the basis of the stepwise dispersed states of the phase errors detected in said dispersion detection section, and

when said oscillator control section calculates a control amount from the mean value of said phase errors, it changes the control amount in a stepwise manner on the basis of the resultant stepwise qualities of the judgment performed in said signal quality judging section, and varies the oscillation frequency of said local oscillator by this control amount.

5. A signal decoding device according to claim 1, wherein said dispersion detection section outputs the detection result of the dispersed state detected in a stepwise manner to an audio control section, and said audio control section determines the muting amount in accordance with the detection result of the stepwise dispersed state so as to perform an audio control.

6. A signal decoding device according to claim 1, wherein said dispersion detection section outputs the detection result of the dispersed state detected in a stepwise manner to an audio control section, and said audio control section determines a control amount of high-pitch tone in accordance with the detection result of the stepwise dispersed states so as to perform an audio control.

7. A method of controlling the reception in a signal decoding device, said signal including a broadcast signal, comprising the steps of:

converting a radio wave captured by an antenna into a signal of medium frequency band,

forming this converted signal of medium frequency band into a digital data,

dividing the digital data into a real-number signal component and an imaginary-number signal component,

performing discrete Fourier transformation to the generated real-number signal component and the imaginary-number signal component,

modulating a time-mode signal into a frequency-mode signal,

detecting and outputting the phases of a carrier, as to all the carriers configuring the broadcast signal from the frequency-modulated real-number signal component data and the imaginary-number signal component data,

controlling a local oscillator by an oscillator control section to vary the oscillation frequency, on the basis of the phases of this carrier, and

controlling the tuner for equalizing the oscillation frequency of the thus controlled local oscillator and that of a local oscillator contained in the timer,

wherein said method further comprises the steps of:

calculating phase errors from the detected phases, detecting the dispersed state of the calculated phase errors, judging the signal quality of the decoded signal from the detected dispersed state of the phase errors, and outputting the judgement result to said oscillator control section.

8. A method of controlling the signal reception in a signal decoding device comprising the steps of:

outputting the phase differences between the phase of a carrier and that of the carrier which is one-symbol before that phase as to all the carriers,
calculating phase errors from the output phase differences,
detecting the dispersed state of the thus calculated phase errors,
judging tether or not the decoded signal is of good quality from the detected dispersed state of the phase errors, and
outputting the judgment result to an oscillator control section.

9. A method of controlling the signal reception in a signal decoding device according to claim 8 characterized by:

detecting the dispersed state of the phase errors calculated from the calculated phase differences in a stepwise manner,
judging whether or not the decoded signal is of good quality is judged from this detected stepwise dispersed state of the phase errors in a stepwise manner,
outputting the judgment result,
varying the control amount in a stepwise manner in accordance with the judged stepwise signal qualities, and
varying the oscillation frequency of a local oscillator from the varied control amount.

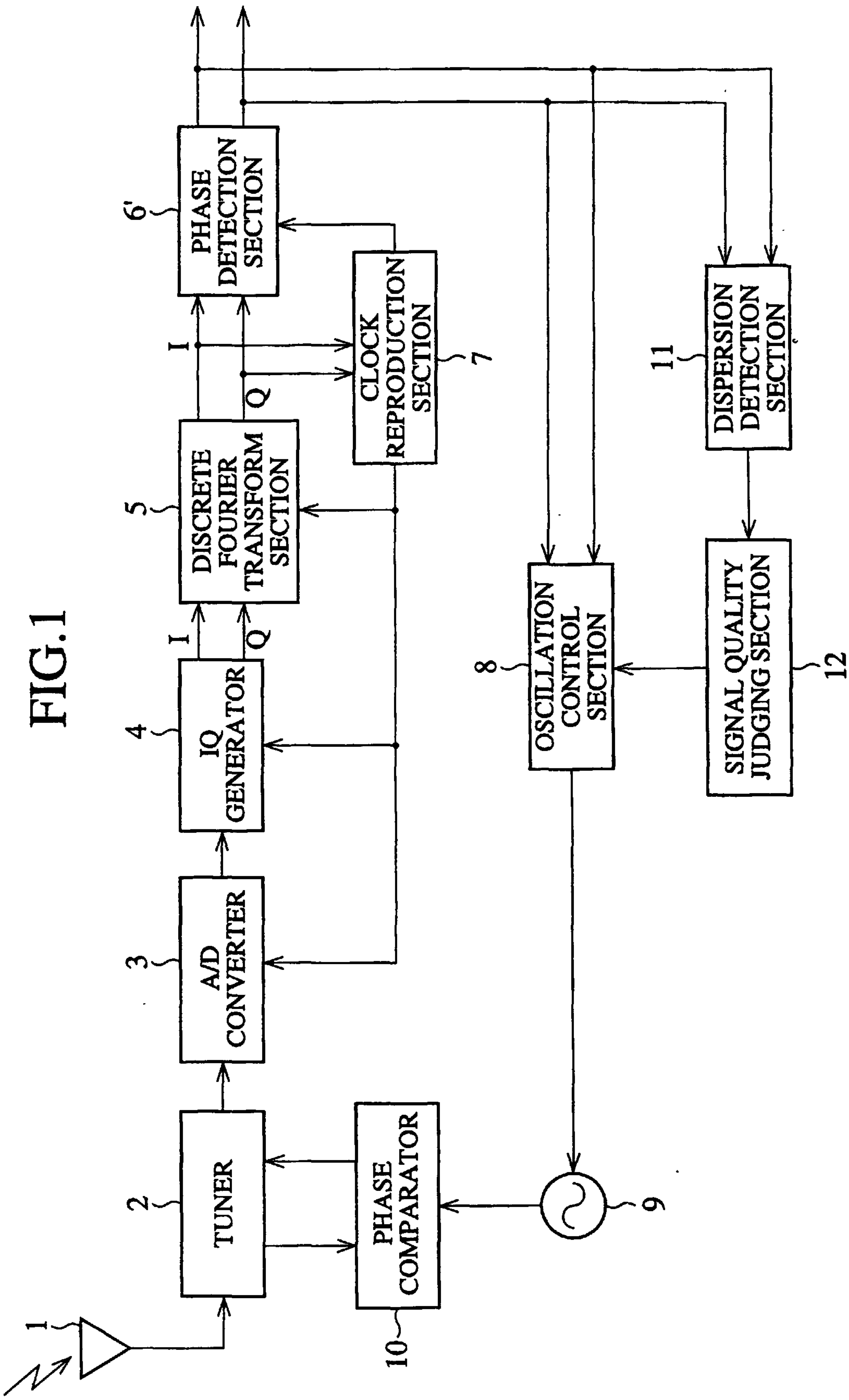
10. A method of controlling the signal reception in a signal decoding device according to claim 8 characterized by:

feeding the judgment result of the dispersed state detected in a stepwise manner to an audio control section, and
determining a muting amount in accordance with the detection result of the stepwise dispersed state, so as to perform an audio control.

11. A method of controlling the signal reception in a signal decoding device according to claim 8 characterized by:

inputting the judgment result of the dispersed state detected in a stepwise manner to an audio control section, and
determining a control amount of high-pitch tone in accordance with the detection result of the stepwise dispersed state, so as to perform art audio control.

FIG.1



1
2
TUNER
10
PHASE COMPARATOR
3
A/D CONVERTER
4
IQ GENERATOR
I
Q
5
DISCRETE FOURIER TRANSFORM SECTION
I
Q
6'
PHASE DETECTION SECTION
7
CLOCK REPRODUCTION SECTION
8
OSCILLATION CONTROL SECTION
9
11
DISPERSION DETECTION SECTION
12
SIGNAL QUALITY JUDGING SECTION

FIG.2

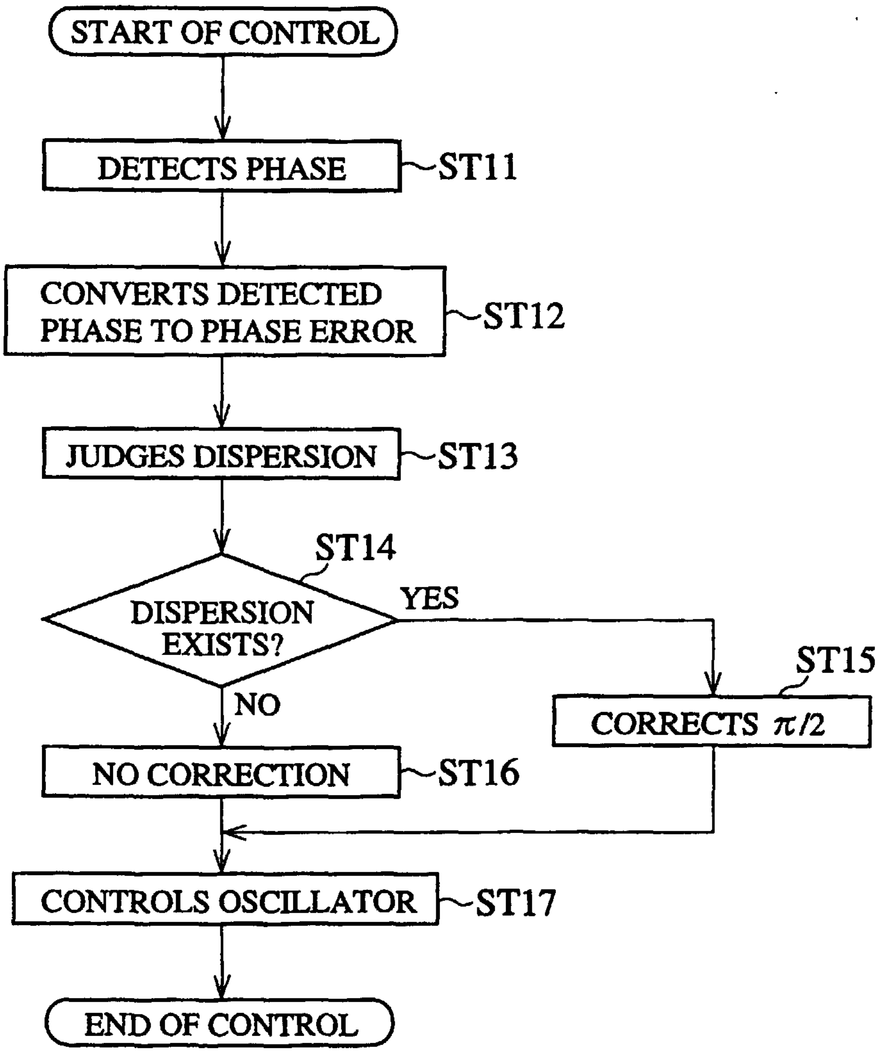

START OF CONTROL
DETECTS PHASE
ST11
CONVERTS DETECTED PHASE TO PHASE ERROR
ST12
JUDGES DISPERSION
ST13
ST14
DISPERSION EXISTS?
YES
ST15
CORRECTS π/2
NO
NO CORRECTION
ST16
CONTROLS OSCILLATOR
ST17
END OF CONTROL

FIG.3

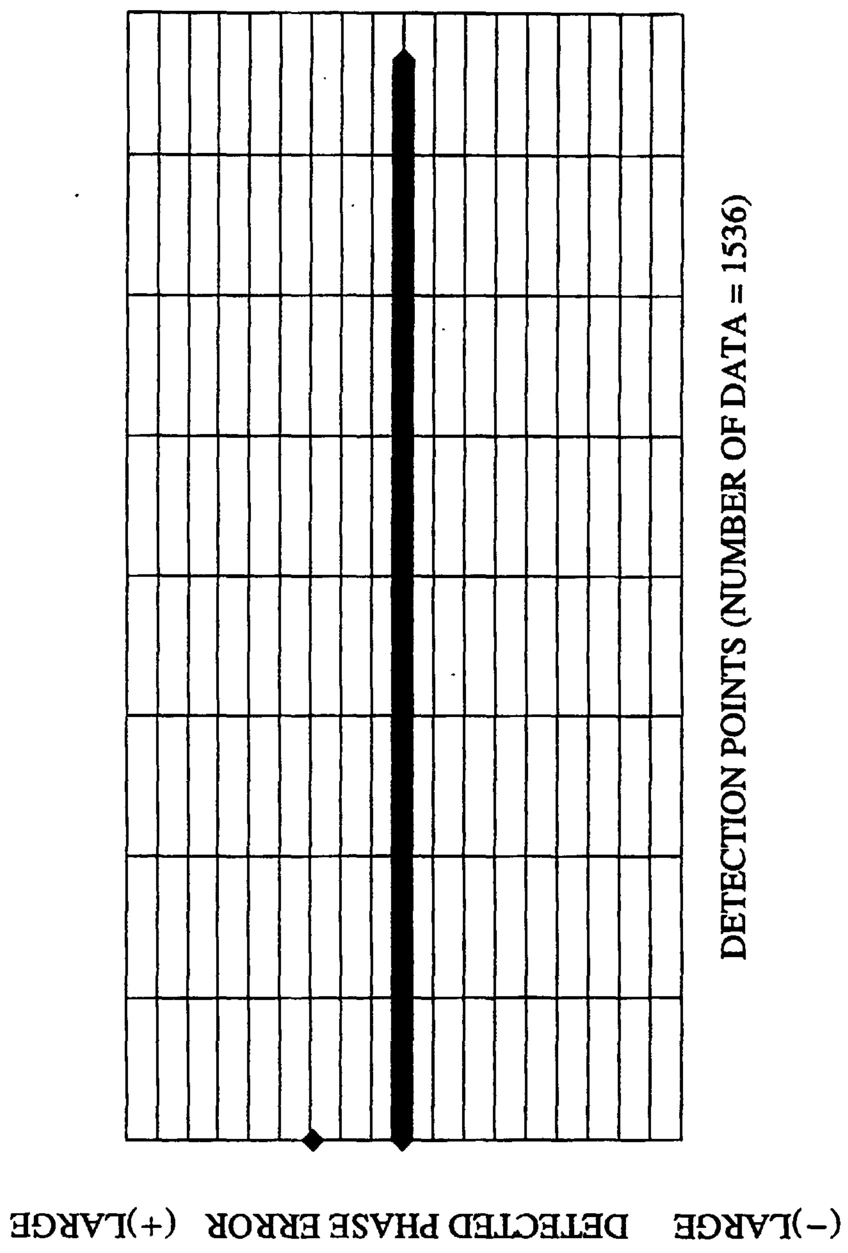

DETECTION POINTS (NUMBER OF DATA = 1536)
(−)LARGE
DETECTED PHASE ERROR
(+)LARGE

FIG.4

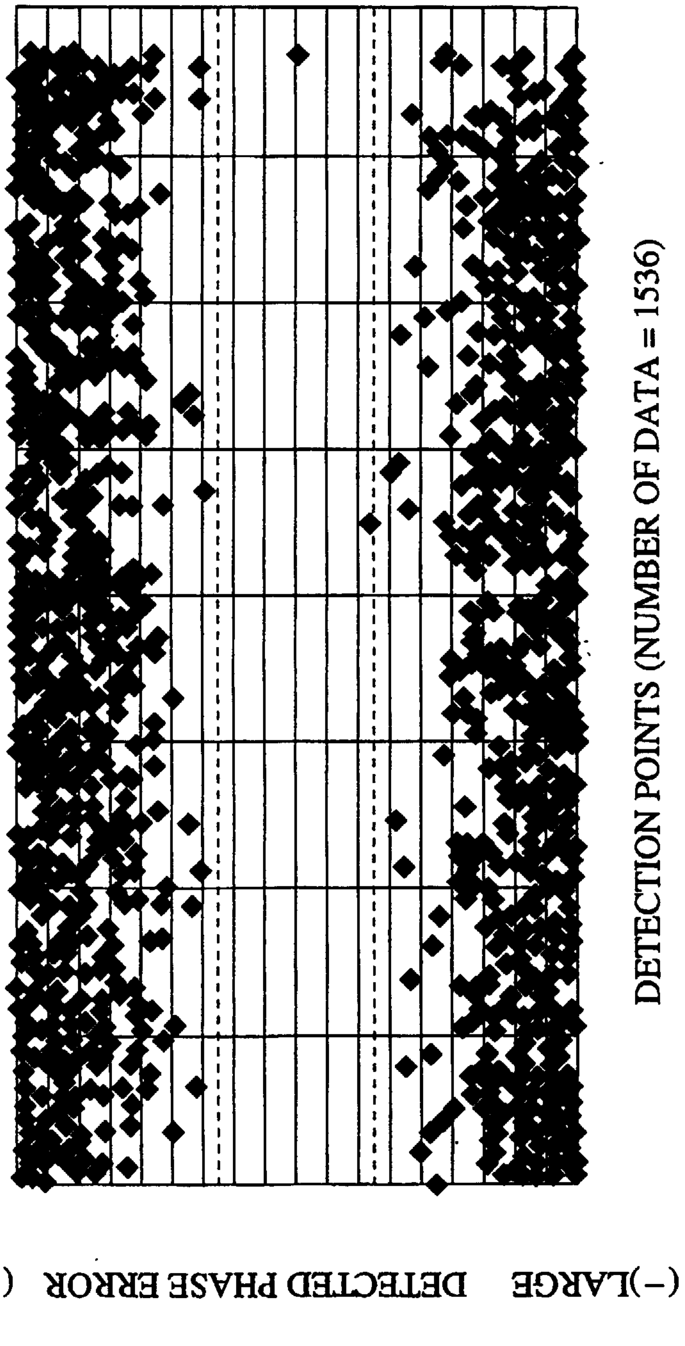

DETECTION POINTS (NUMBER OF DATA = 1536)
(−)LARGE DETECTED PHASE ERROR (+)LARGE

FIG.5

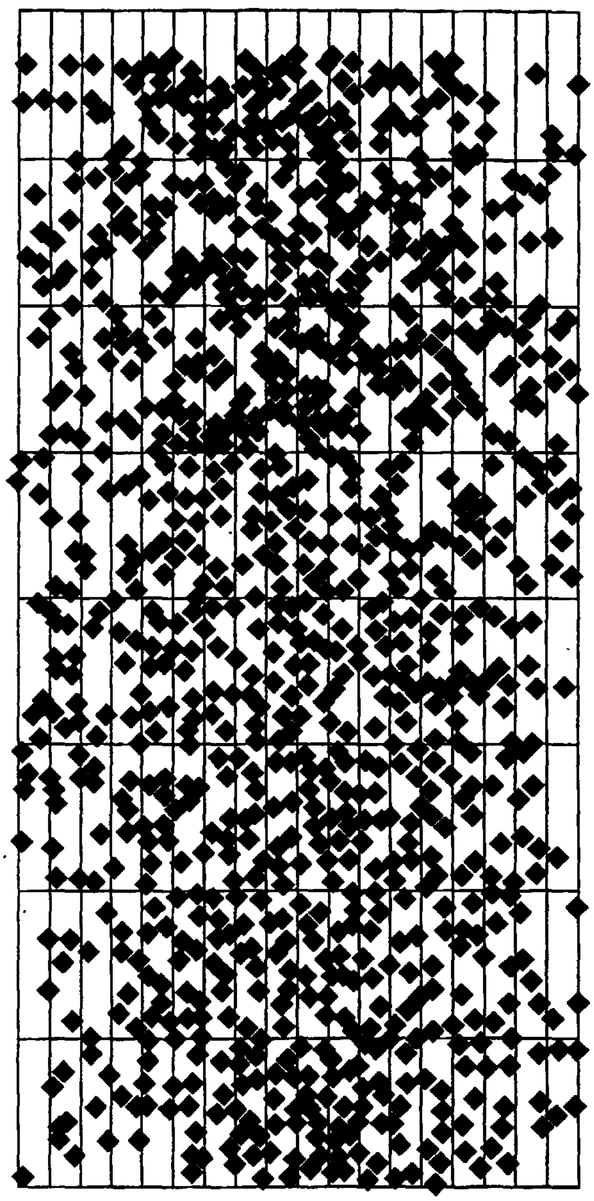

DETECTION POINTS (NUMBER OF DATA = 1536)
(−)LARGE DETECTED PHASE ERROR (+)LARGE

FIG.6

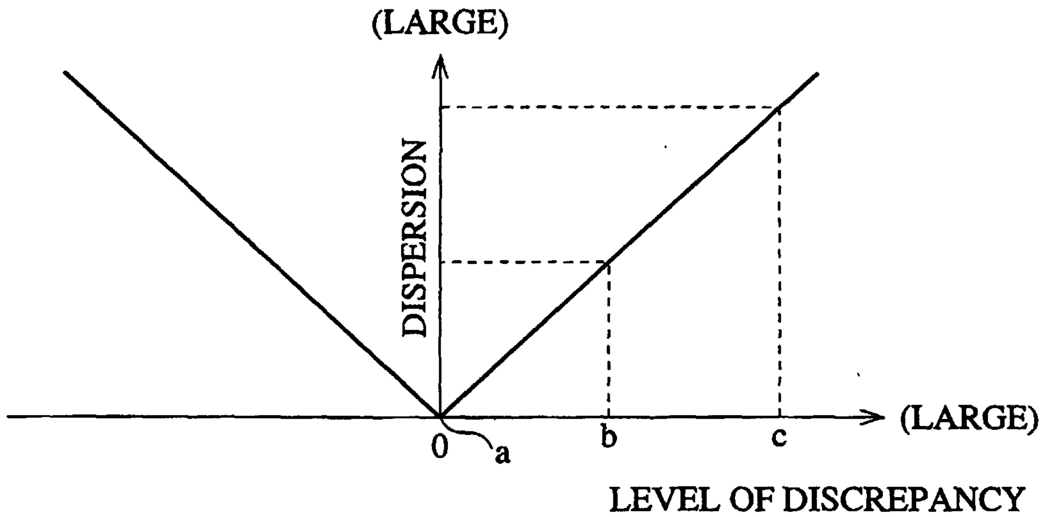


FIG.7

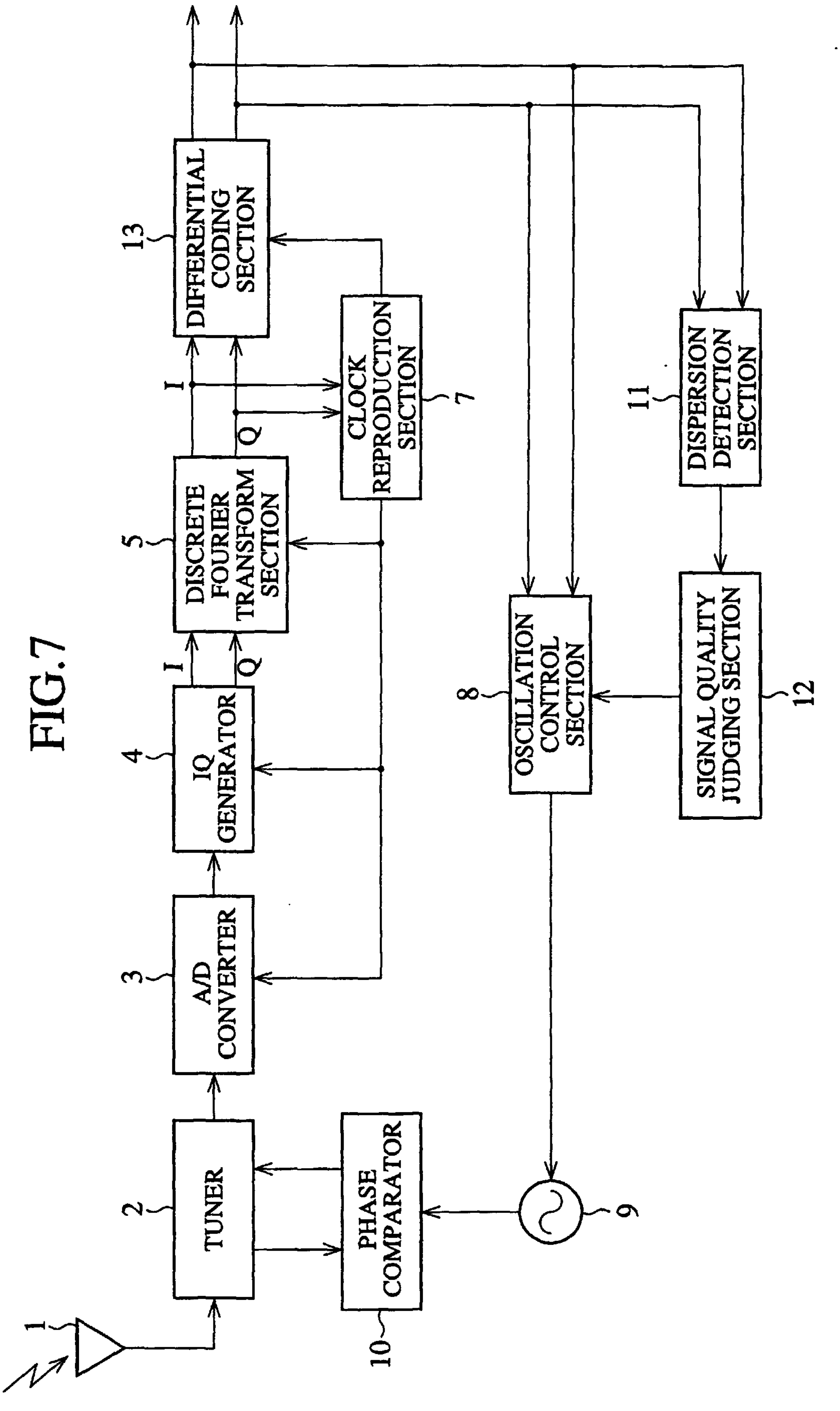

1
TUNER
2
PHASE COMPARATOR
10
A/D CONVERTER
3
IQ GENERATOR
4
I
Q
DISCRETE FOURIER TRANSFORM SECTION
5
CLOCK REPRODUCTION SECTION
7
DIFFERENTIAL CODING SECTION
13
OSCILLATION CONTROL SECTION
8
9
DISPERSION DETECTION SECTION
11
SIGNAL QUALITY JUDGING SECTION
12

FIG.8

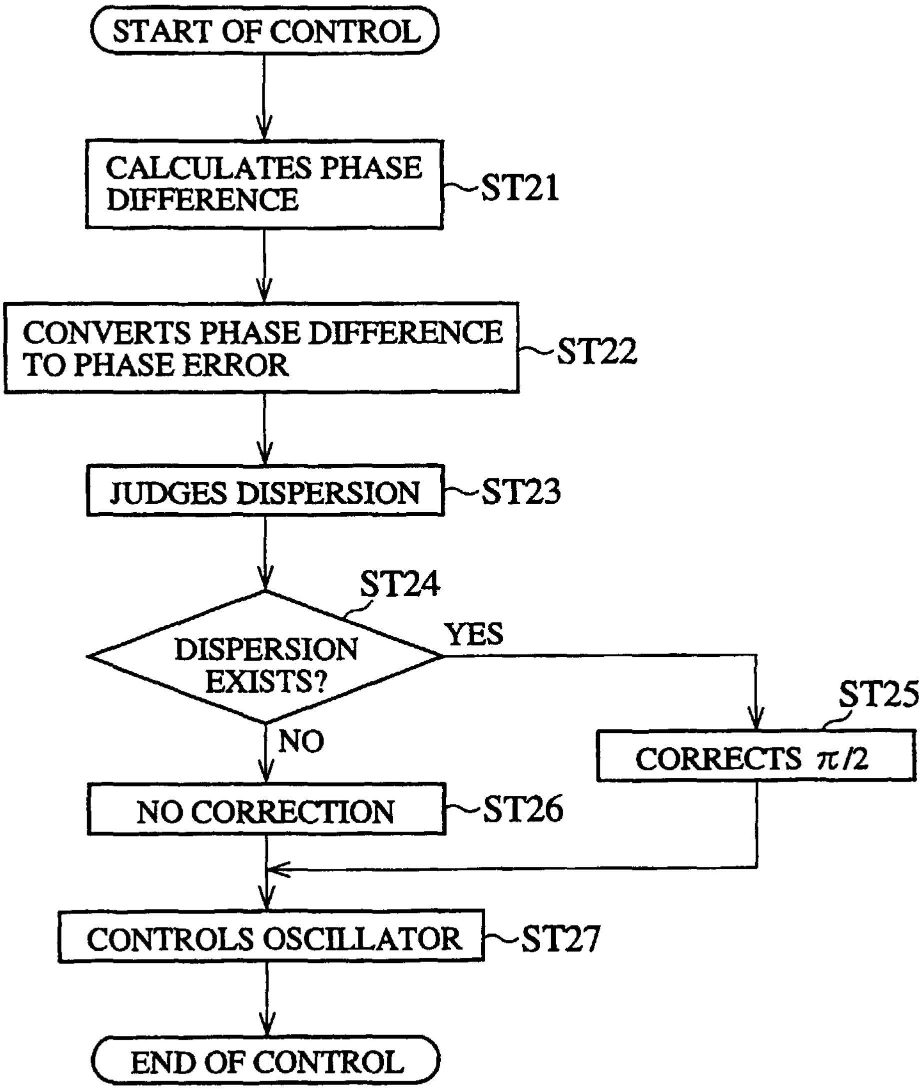

START OF CONTROL
CALCULATES PHASE DIFFERENCE
ST21
CONVERTS PHASE DIFFERENCE TO PHASE ERROR
ST22
JUDGES DISPERSION
ST23
ST24
DISPERSION EXISTS?
YES
NO
ST25
CORRECTS π/2
NO CORRECTION
ST26
CONTROLS OSCILLATOR
ST27
END OF CONTROL

FIG.9

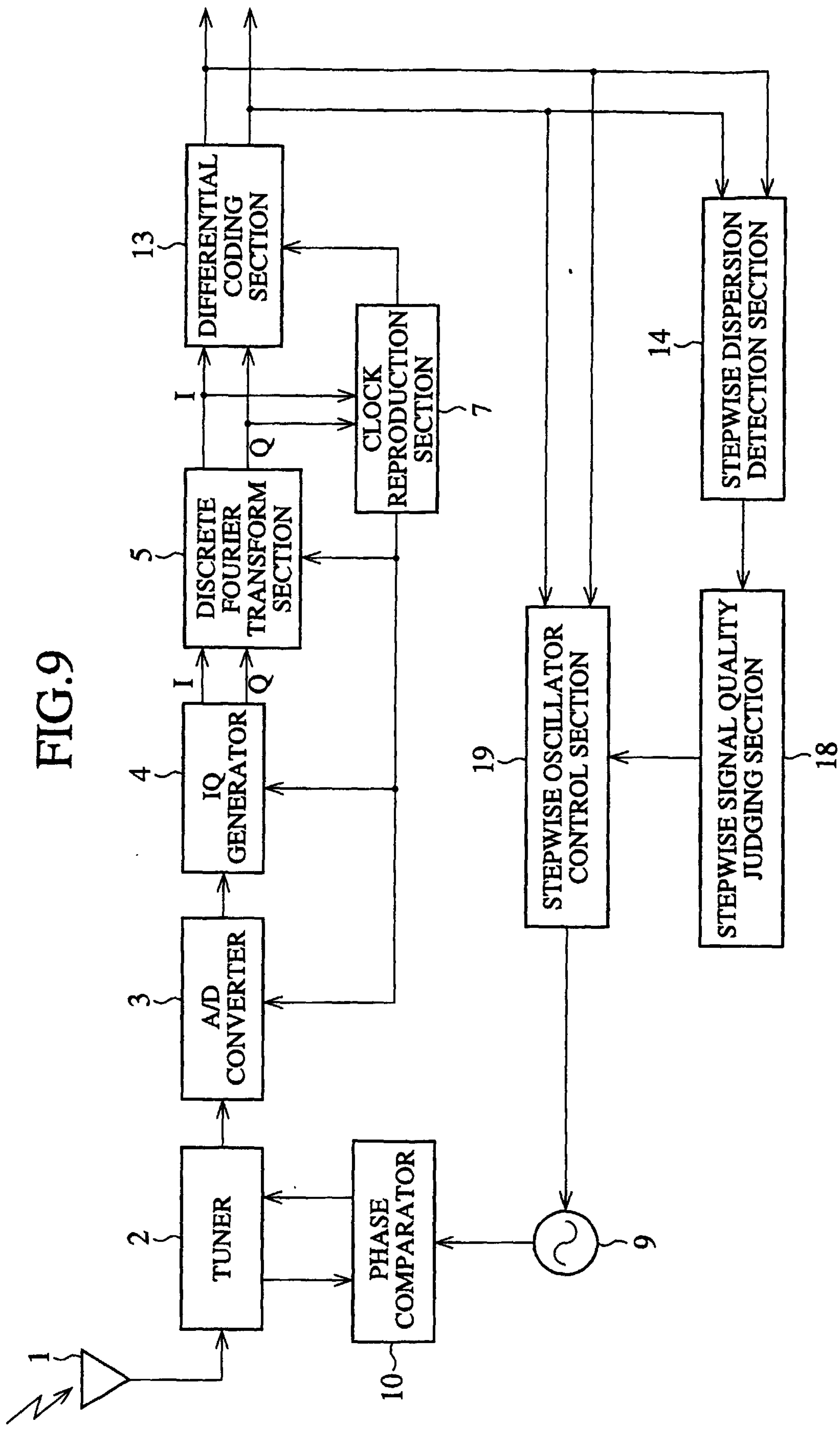

1
TUNER
2
A/D CONVERTER
3
IQ GENERATOR
4
I
Q
DISCRETE FOURIER TRANSFORM SECTION
5
I
Q
DIFFERENTIAL CODING SECTION
13
CLOCK REPRODUCTION SECTION
7
PHASE COMPARATOR
10
9
STEPWISE OSCILLATOR CONTROL SECTION
19
STEPWISE DISPERSION DETECTION SECTION
14
STEPWISE SIGNAL QUALITY JUDGING SECTION
18

FIG.10

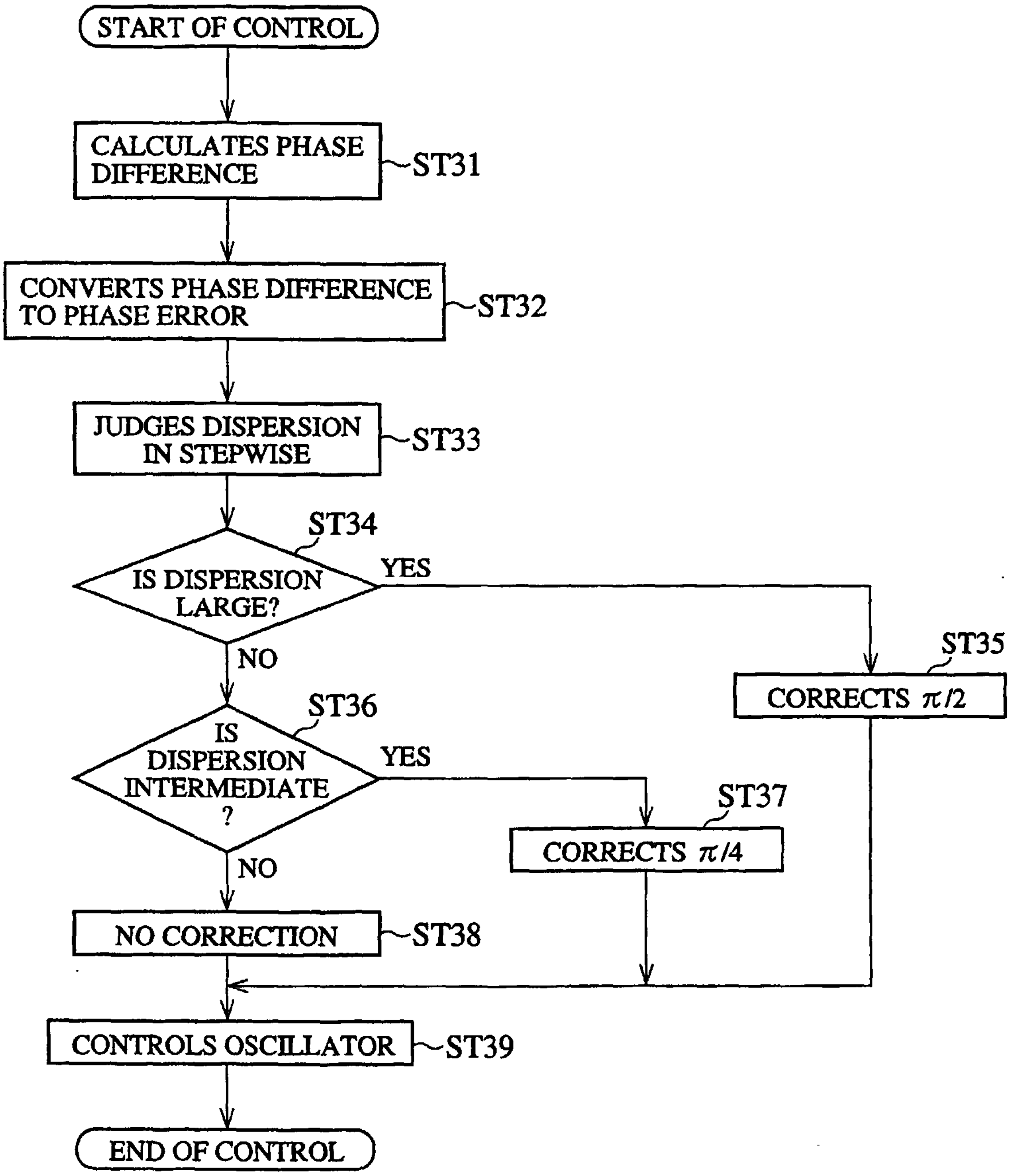

START OF CONTROL
CALCULATES PHASE DIFFERENCE
ST31
CONVERTS PHASE DIFFERENCE TO PHASE ERROR
ST32
JUDGES DISPERSION IN STEPWISE
ST33
ST34
IS DISPERSION LARGE?
YES
NO
ST35
CORRECTS π/2
ST36
IS DISPERSION INTERMEDIATE ?
YES
NO
ST37
CORRECTS π/4
NO CORRECTION
ST38
CONTROLS OSCILLATOR
ST39
END OF CONTROL

FIG.11

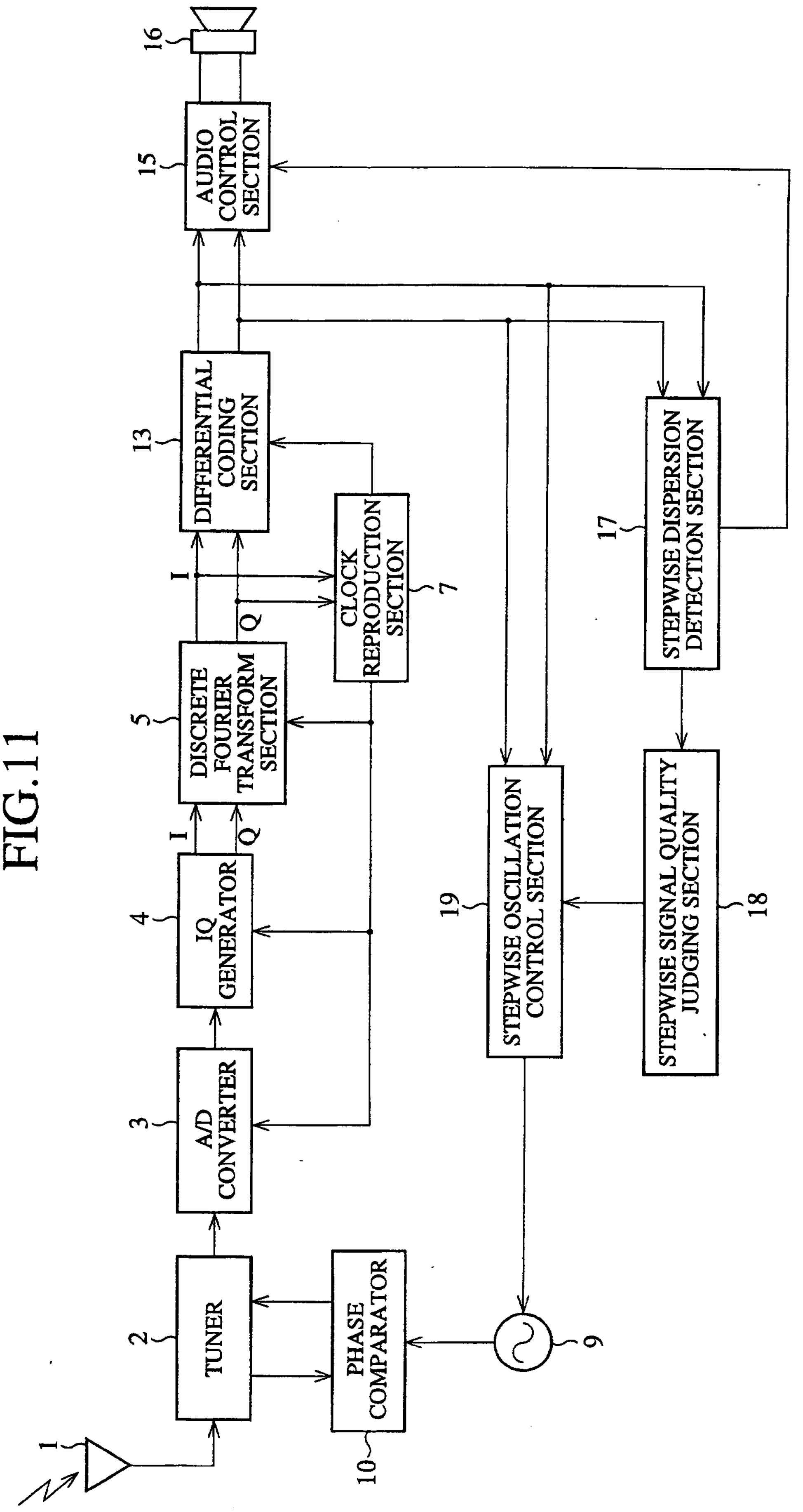

1
2
TUNER
3
A/D CONVERTER
4
IQ GENERATOR
I
Q
5
DISCRETE FOURIER TRANSFORM SECTION
I
Q
7
CLOCK REPRODUCTION SECTION
13
DIFFERENTIAL CODING SECTION
15
AUDIO CONTROL SECTION
16
10
PHASE COMPARATOR
9
19
STEPWISE OSCILLATION CONTROL SECTION
18
STEPWISE SIGNAL QUALITY JUDGING SECTION
17
STEPWISE DISPERSION DETECTION SECTION

FIG.12

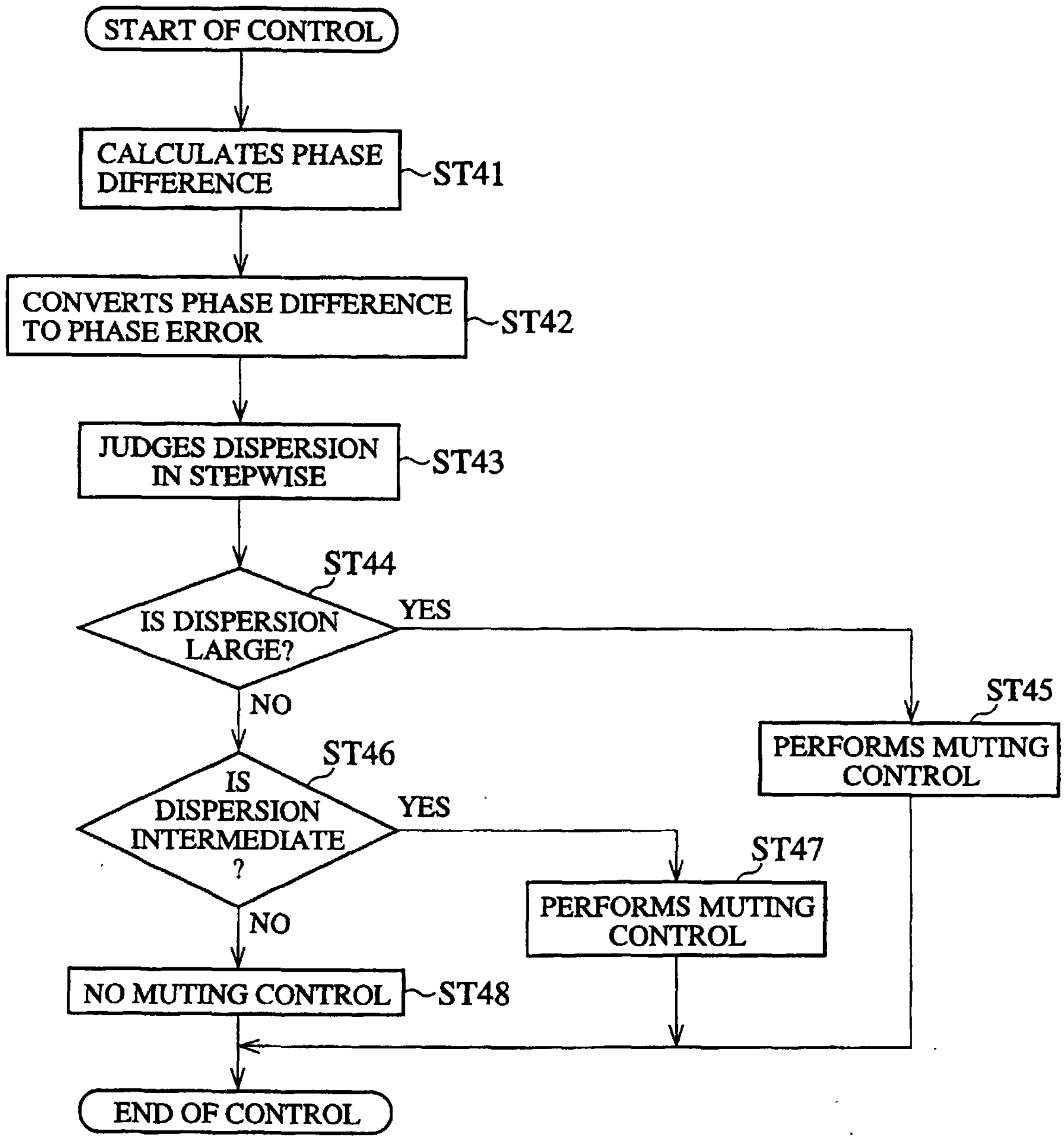

START OF CONTROL
CALCULATES PHASE DIFFERENCE
ST41
CONVERTS PHASE DIFFERENCE TO PHASE ERROR
ST42
JUDGES DISPERSION IN STEPWISE
ST43
ST44
IS DISPERSION LARGE?
YES
NO
ST45
PERFORMS MUTING CONTROL
ST46
IS DISPERSION INTERMEDIATE ?
YES
NO
ST47
PERFORMS MUTING CONTROL
NO MUTING CONTROL
ST48
END OF CONTROL

FIG.13

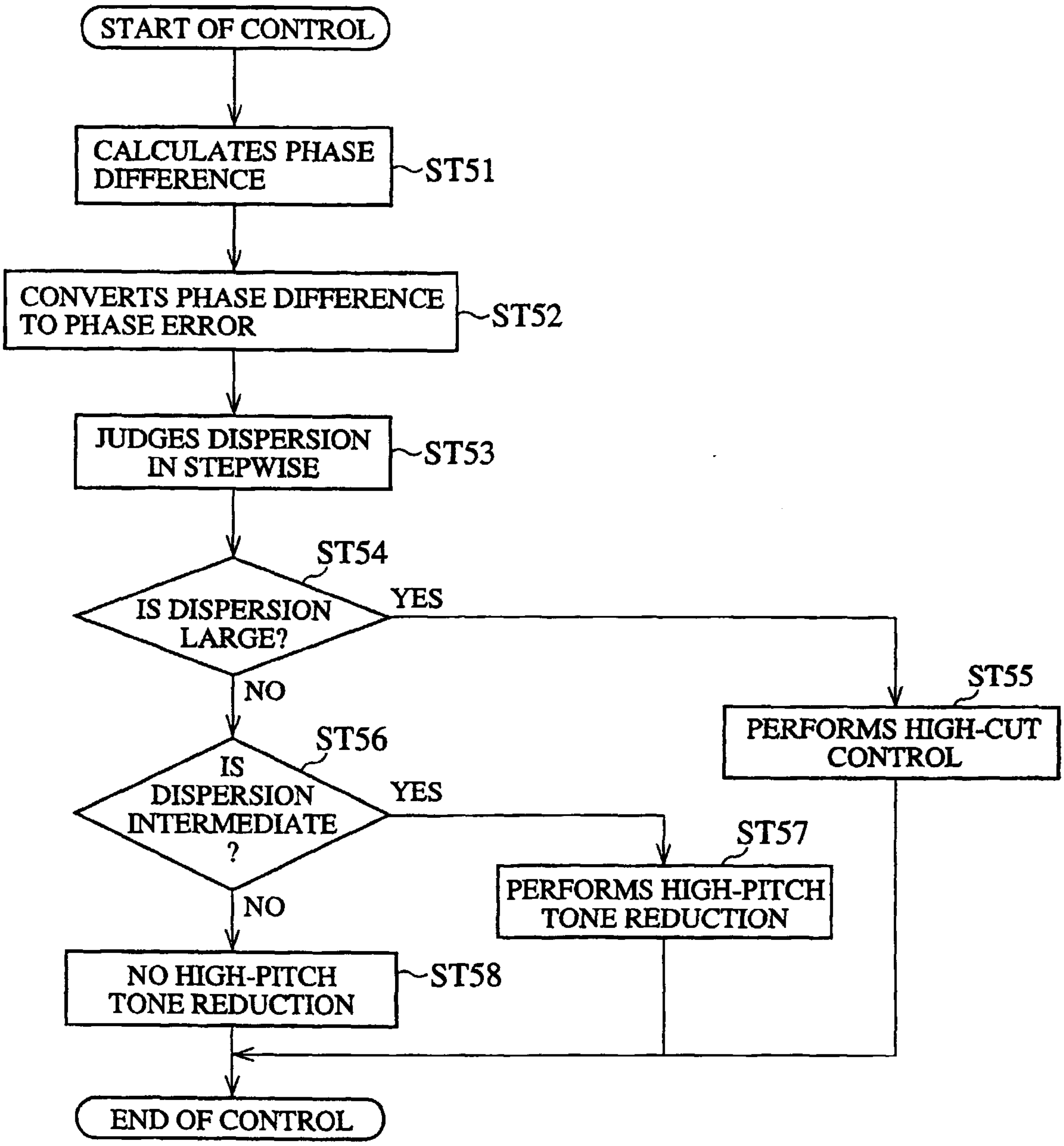

START OF CONTROL
CALCULATES PHASE DIFFERENCE
ST51
CONVERTS PHASE DIFFERENCE TO PHASE ERROR
ST52
JUDGES DISPERSION IN STEPWISE
ST53
ST54
IS DISPERSION LARGE?
YES
NO
ST55
PERFORMS HIGH-CUT CONTROL
ST56
IS DISPERSION INTERMEDIATE ?
YES
NO
ST57
PERFORMS HIGH-PITCH TONE REDUCTION
NO HIGH-PITCH TONE REDUCTION
ST58
END OF CONTROL

FIG.14

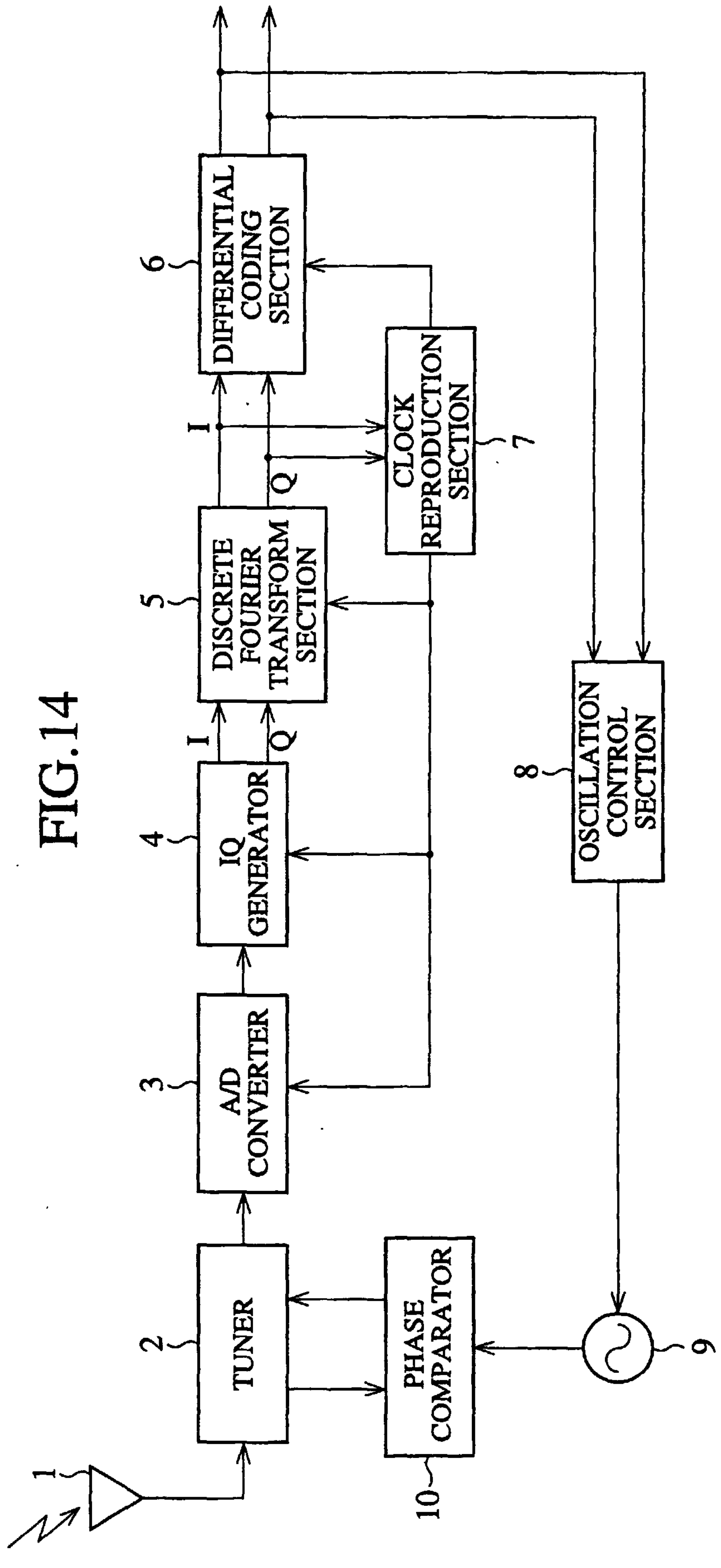

1
TUNER
2
PHASE COMPARATOR
10
A/D CONVERTER
3
IQ GENERATOR
4
I
Q
DISCRETE FOURIER TRANSFORM SECTION
5
I
Q
CLOCK REPRODUCTION SECTION
7
DIFFERENTIAL CODING SECTION
6
OSCILLATION CONTROL SECTION
8
9

FIG.15

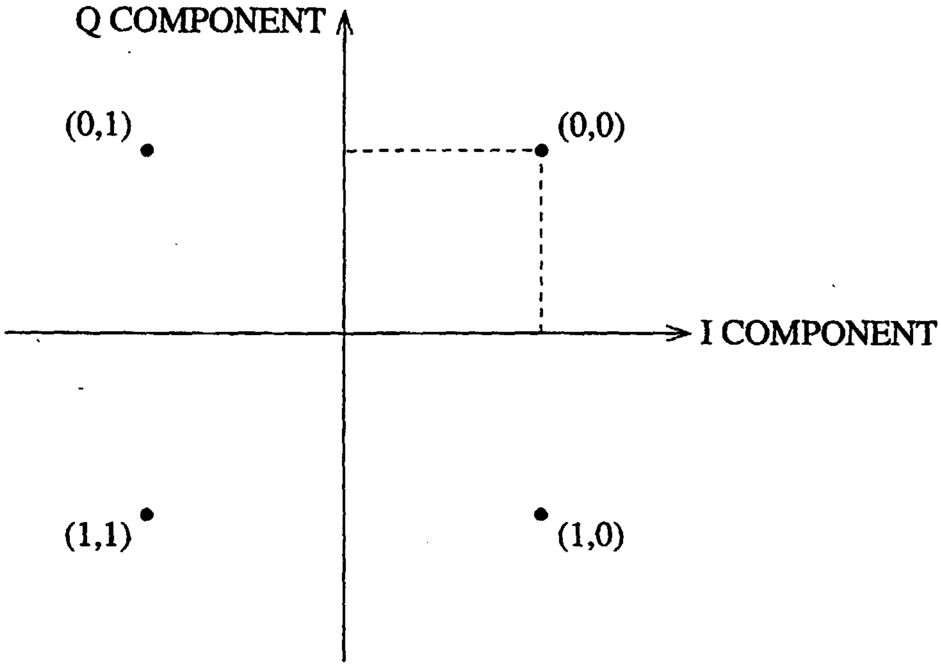

Q COMPONENT
(0,1)
(0,0)
I COMPONENT
(1,1)
(1,0)

FIG.16

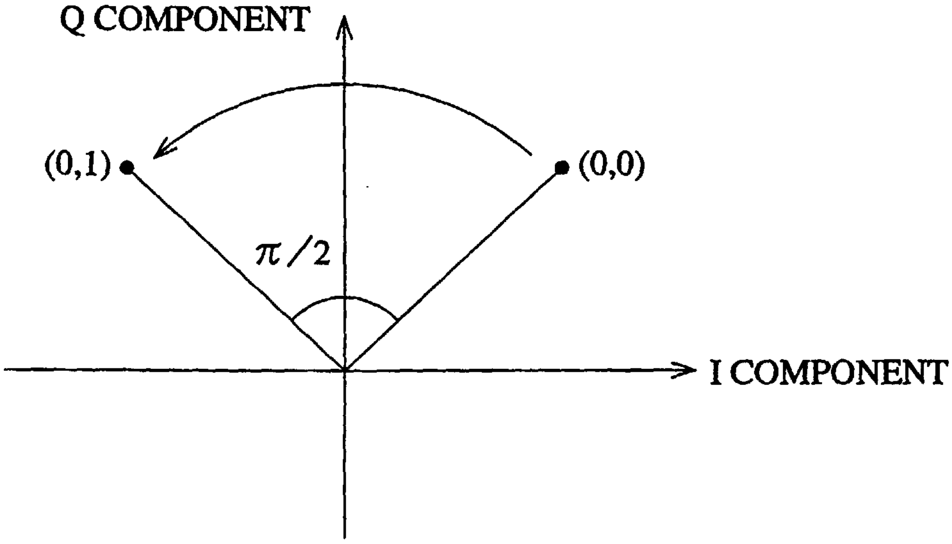
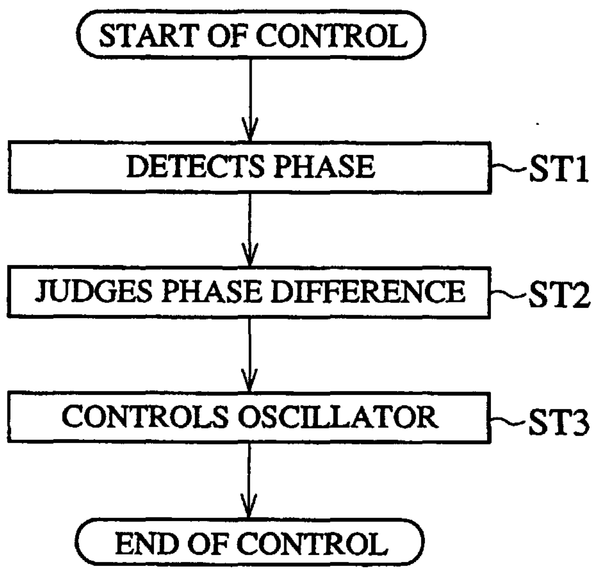

Q COMPONENT
(0,1)
(0,0)
π/2
I COMPONENT

FIG.17


START OF CONTROL
DETECTS PHASE
ST1
JUDGES PHASE DIFFERENCE
ST2
CONTROLS OSCILLATOR
ST3
END OF CONTROL

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/03742

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[6] H04J11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[6] H04J11/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho (Y1, Y2) 1926-1998 Toroku Jitsuyo Shinan Koho (U) 1994-1998
Kokai Jitsuyo Shinan Koho (U) 1971-1998 Jitsuyo Shinan Toroku Koho (Y2) 1996-1998

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP, 7-95175, A (Toshiba Corp.), 7 April, 1995 (07. 04. 95), Fig. 1 (Family: none)	8
X	JP, 7-143096, A (Toshiba Corp.), 2 June, 1995 (02. 06. 95), Fig. 1 (Family: none)	8
A	JP, 4-501348, A (Thomson-CSF), 5 March, 1992 (05. 03. 92), Fig. 21 & WO, 90-04893, A	1-7, 9-11

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 November, 1998 (16. 11. 98)	24 November, 1998 (24. 11. 98)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)